Extension - Upgrading Methane Using Ultra-Fast Thermal Swing Adsorption

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by
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Abstract

The purpose of this project is to develop a cost effective technology for upgrading coal mine methane to natural gas pipeline quality. Nitrogen rejection is the most costly step with conventional technology and emerging competitive technology. Significant cost reductions to this step will allow for the cost effective capture and utilization of this otherwise potent greenhouse gas. The proposed approach is based on the microchannel technology platform that Velocys is developing to commercialize compact and cost efficient chemical processing technology. For this application, ultra fast thermal swing adsorption is enabled by the very high rates of heat transfer enabled by microchannels.

Natural gas upgrading systems have six main unit operations: feed compressor, dehydration unit, nitrogen rejection unit, deoxygenator, carbon dioxide scrubber, and a sales compressor. The NRU is the focus of the development program, and a bench-scale demonstration has been initiated. The Velocys NRU system targets producing methane with greater than 96% purity and at least 90% recovery for final commercial operation. A preliminary cost analysis of the methane upgrading system, including the Velocys NRU, suggests that costs below $2.00 per million (MM) BTU methane may be achieved. The cost for a conventional methane upgrading system is well above $2.30 per MM BTU, as benchmarked in an Environmental Protection Agency study.

Initial performance results for the Velocys TSA technology were promising. Velocys has also completed initial discussions with several prospective users of the technology and received positive market feedback. Some of the factors that create an attractive opportunity for the technology include the sustained high prices for natural gas, the emerging system of carbon credits, and continued focus on reducing coal mine emissions. While market interest has been confirmed, improvements and optimization are necessary to move the technology to a point that will enable commercial investment in the technology scale-up. In particular, prospective industry collaborators are interested in seeing validation that the technology can meet real-world conditions, including handling impurities, meeting purity and recovery targets (which requires low dead volume), and meeting cost and manufacturability goals.

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Executive Summary

The purpose of this project is to develop a cost effective technology for upgrading coal mine methane to natural gas pipeline quality. Nitrogen rejection is the most costly step with conventional technology and emerging competitive technology. Significant cost reductions to this step will allow for the cost effective capture and utilization of this otherwise potent greenhouse gas. The proposed approach is based on the microchannel technology platform that Velocys is developing to commercialize compact and cost efficient chemical processing technology. For this application, ultra fast thermal swing adsorption is enabled by the very high rates of heat transfer enabled by microchannels

The objective of the project extension over 24 months is to further evaluate the microchannel technology under real world processing conditions. Five main objectives are proposed:

- Identify one or more commercial absorbents that can meet the purity and recovery requirements for pipeline specifications
- Demonstrate that the absorbents can operate with real feed mixtures of coal mine methane streams
- Demonstrate that the bench-scale adsorber meets the purity, recovery, and durability requirements
- Confirm manufacturability of absorber units and identify critical development needs
- Show that the technology meets industry's economic targets for capital and operating costs

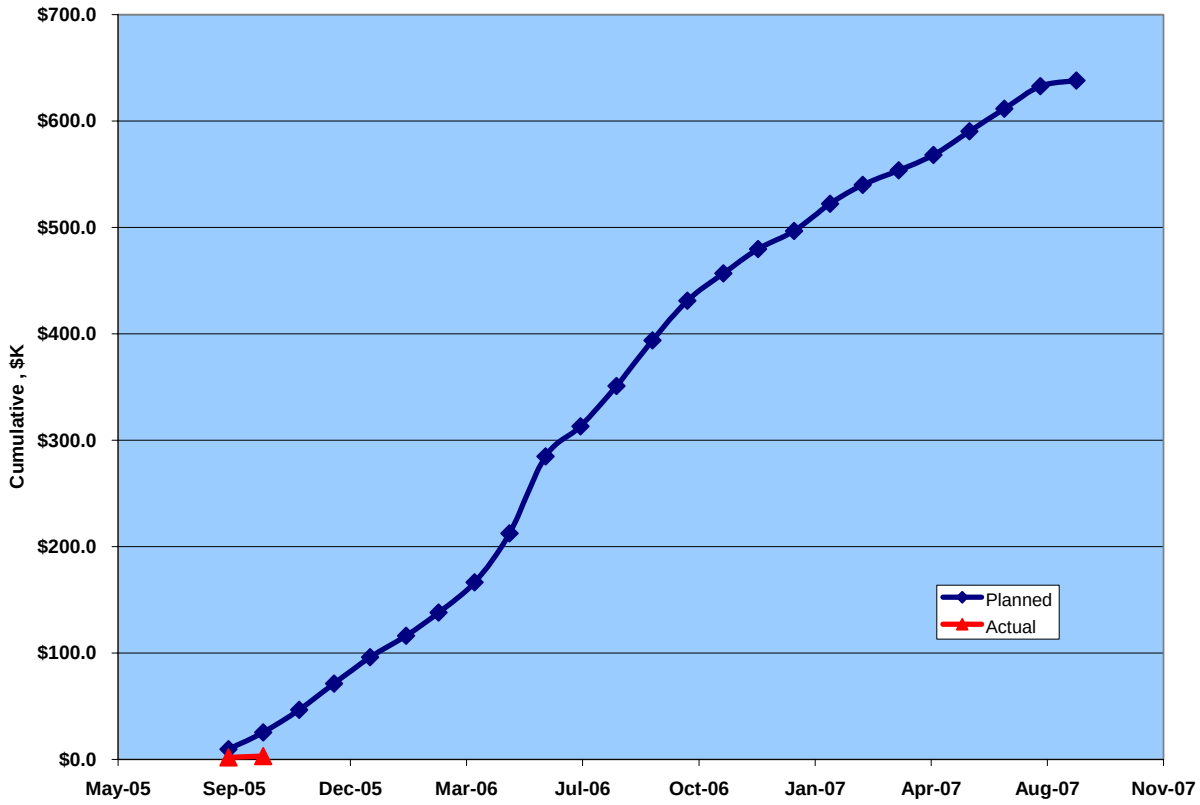
During the initial phase of the project, a number of key technical accomplishments were completed including:

- The thermal swing adsorption project demonstrated sufficient initial adsorbent differential capacity for methane and nitrogen on microporous carbon. The best differential capacity was at 100 psig between 40°C and 60°C, where roughly 10 mg/gm methane and less than 1 mg/gm nitrogen were observed.
- A preliminary system and component design were performed to understand the requirements for process economics.
- An initial bench-scale demonstration was completed with a single cylindrical channel device, where a thermal swing time of 10 seconds for a bed differential temperature of 20°C was measured.
- A feed stream of 70% methane and 30% nitrogen was separated and purified to a mixture of 92% methane and 8% nitrogen with the use of an interstage purge to flush out the large dead volume on the test system.

The status of all tasks is listed below:

- Task 1: Evaluate improved and optimized adsorbents – *ongoing*
- Task 2: Evaluate feed mixtures with major contaminants – *pending*
- Task 3: Demonstrate the bench-scale adsorber with reduced system dead volume and with a real feed mixture and improved adsorbent – *pending*

- Task 4: Develop preliminary manufacturing plan for full-scale microchannel units and identify critical development needs – *pending*
- Task 5: Update system design and cost based on thermal integration with coal-mine methane upgrading plants – *pending*
- Task 6: Commercialize Technology – *pending*
- Task 7: Project Management – *ongoing*



Actual and Budgeted Cumulative Project Costs

The project has started slowly and we remain below budget early into the project.

Experimental

The project has initiated with an investigation into improved adsorbent options for use in the nitrogen rejection application. The evaluation has expanded in breadth to include structured adsorbents, including foams, felts, cloths, and the like.

Important parameters for consideration in evaluating new materials include:

- Thermal conductivity: to swing the bed faster
- Heat capacity: to reduce the amount of energy required to swing the bed
- Capacity: increase the uptake of methane
- Cost: integrate cost competitive and manufacturable structures into microchannel devices

Results and Discussion

Initial discussion with Calgon Carbon have identified a family of adsorbents, carbon cloths, with reported values of capacity near those measured and reported previously with the highly microporous granular form of activated carbon. The materials have been procured and testing evaluation is set to start in the first quarter of FY05, ahead of schedule.

- Thermal conductivity: The material is reported to be anisotropic with respect to thermal conductivity, and measurements will be conducted to ascertain final values.

- Heat capacity: Reported values of heat capacity are on the order of 25% below the granular form of carbon. In turn, this should reduce the total amount of energy required to thermally swing the adsorption unit.

- Capacity: Reported values from the manufacturer are suggested to approach those measured with the granular form selected in the previous development phase of this project.

- Cost: The initial cost of the material is suggestive of approaching less than 10% of the cost of the final microchannel adsorption unit – and reasonable to continue consideration.

Conclusions

Work is accelerating to evaluate structured carbon as an adsorbent in microchannel devices for use in nitrogen rejection.

Acronyms and Abbreviations

Btu	British thermal unit
GHG	greenhouse gas
gm	gram
GWP	global warming potential
HPBV	high-performance butterfly valve
kg	kilogram
mg	milligram
MMSCFD	million standard cubic feet per day
MW	megawatts
NRU	nitrogen rejection unit
psig	pound per square inch gauge
SLPM	standard liters per minute
TSA	thermal swing adsorption

Public Recognition of the Project

A publication has been accepted for oral presentation at ACHEMA 2006 in Frankfurt Germany on the use of thermal swing adsorption in a microchannel for nitrogen rejection.